> [1]**sol-id** ... **1 a :** having an interior filled with matter; being without an internal cavity ... opposed to hollow ...
>
> [3]**solid** ... **3 :** something (as a substantial mass) that is solid as **a :** compact mass of masonry or comparable fabrication (as a wall or pier) as distinguished from one containing a void or an opening ...

See also, use of the term "solid" to characterize the solid core of a golf ball in Claim 1 at lines 1-2 of U.S. Patent No. 4,431,193 and to characterize a solid needle in Claim 1 at line 2 of U.S. Patent No. 4,431,137 (copies enclosed).

Based on its ordinary dictionary meaning, as demonstrated hereinabove, the term "solid" as used in claim 10 unequivocally defines structure, and distinguishes claim 10 over the newly applied U.S. Patent No. 6,123,705 to Michelson for reasons stated in the Response and Amendment Under rule 116 filed on July 27, 2009.

Even if the Examiner deems the foregoing not persuasive, entry of the previously proposed amendment to claim 10 is requested because it places claim 10 in a better condition for appeal.

Kindly charge any necessary extension fee required for consideration of this Further Response Under Rule 116 and to Advisory Action to our Deposit Account No. 15-0508.

Respectfully submitted,

August 24, 2009

By Talivaldis Cepuritis
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Enclosures: Page 2169, Webster's Third New International Dictionary of the English Language, Unabridged (3 pp.)
U.S. Patent No. 4,431,193
U.S. Patent No. 4,431,137

CERTIFICATE OF FACSIMILE TRANSMISSION

I hereby certify that this FURTHER RESPONSE UNDER RULE 116 AND TO ADVISORY ACTION, is being transmitted by facsimile transmission to Fax No. 571-273-8300 on August 24, 2009.

Talivaldis Cepuritis

Talivaldis Cepuritis (Reg. No. 20,818)

Webster's Third New International Dictionary

OF THE ENGLISH LANGUAGE UNABRIDGED

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L *solum* ground, base] 1 : a set of Spanish sherry vats arranged in tiers usu. three high in a storage shed 2 *also* **solera system** : a system evolved by the sherry producers of Jerez, Spain, whereby young wine in the vats of the top tier of a solera is successively blended into the more mature wine in the vats on the tier below to insure ultimate uniformity 3 *also* **solera sherry** *or* **solera wine** : a wine aged by the Spanish solera system

soles *pl of* SOL, *or of* SOLE, *pres 3d sing of* SOLE

sole tile *n* ['sole] : a tile with a concave top used esp. to pave sewers

sole tree *n* ['sole] : a solepiece used in a mine (as for timbering headings)

so·le·us \'sōlēəs\ *n, pl* **so·lei** \-ē,ī\ *also* **soleuses** [NL, fr. L *solea* sole of the foot] : a broad flat muscle of the calf of the leg lying immediately below the gastrocnemius, arising from the back and upper part of the tibia and fibula and from a tendinous arch between them, and inserting by a tendon that unites with that of the gastrocnemius to form the Achilles' tendon

¹sol-fa \(')sōl'fä, -fȧ, *chiefly Brit* ('sōl-\ *n* -s ['sol + *fa*] 1 : SOL-FA SYLLABLES 2 : GREAT SCALE 3 a : SOLMIZATION b : an exercise sung in sol-fa syllables 4 : TONIC SOL-FA

²sol-fa \"\ *vb* -ED/-ING/-S *vt* 1 : to drill or practice the tones of the gamut or scale 2 : to sing in sol-fa syllables ~ *vi* : to sing (as an air or song) to or in sol-fa syllables

sol-fa·er \-ə(r)\ *n* -s [*sol-fa* + *-er*] : one that sol-fas

sol-fa·ist \-əst\ *n* -s [*sol-fa* + *-ist*] : a user or an advocate of the tonic sol-fa system

sol-fa syllables *n pl* : the eight modified Guidonian syllables *do, re, mi, fa, sol, la, ti, do* applied to reading music for the major scale and further modified for the chromatic scale ascending and descending to *do, di, re, ri, mi, fa, fi, sol, si, la, li, ti, do, ti, te, la, le, sol, se, fa, mi, me, re, ra, do* — compare MOVABLE-DO SYSTEM, SOLMIZATION

sol·fa·ta·ra \,sōlfə'tärə, ,säl-\ *n* -s [It, sulfur mine, sulphurous vent, fr. *solfo* sulphur, fr. L *sulfur*] : a volcanic area or vent that yields only hot vapors and gases in part sulfurous and represents a late stage of volcanic activity

sol·fa·tar·ic \;==;tarik, -,tär-\ *adj* 1 : of or relating to a solfatara or its action 2 : relating to, caused by, or denoting the transfer of mineral substances within the earth by sublimation or by the chemical and transporting action of steam

sol·fège \(')säl'fezh\ *n* -s [F, fr. It *solfeggio*] 1 : the application of the sol-fa syllables to the tones of the musical scale or to melodies or other voice parts 2 : an exercise in scales; *specif* : a singing exercise using sol-fa syllables 3 : practice in sight-singing using the sol-fa syllables

sol·feg·gio \säl'fe(,)jō, -ej(ē),ō\ *n, pl* **solfeg·gi** \-e(,)jē\ *also* **solfeggios** [It, fr. *solfeggiare* to sol-fa, fr. *solfa* sol-fa, fr. *sol* (fr. ML) + *fa* (fr. ML) — more at SOL, FA] : SOLFÈGE

sol·fe·ri·no \,sälfə'rē(,)nō\ *n* -s [fr. *Solferino*, village of northern Italy; fr. its being discovered soon after the battle fought there in 1859] 1 : FUCHSINE 1 2 : a moderate purplish red that is redder, darker, and slightly stronger than average rose, redder and duller than violine pink, redder and paler than magenta rose, and redder and less strong than average fuchsia rose

solgel \'=;=\ *adj* [*sol* + *gel*] : involving alternation between sol and gel states — used esp. of protoplasmic phenomena (~ transformations in the amoeba)

¹soli *pl of* SOLO

²so·li \'sō(,)lē\ *adj* [*soli*] : constituting a solo part usu. to be performed by a section or part of a section in an orchestra or a chorus (~ parts) (~ strings)

soli- *comb form* [L, fr. *solus* — more at SOLE] : alone : solely (*soliloquy*) (*solifidian*)

so·lic·it \sə'lisət, *usu* -əd·+V\ *vb* -ED/-ING/-S [ME *soliciten*, fr. MF *solliciter*, *soliciter* to disturb, take care of (influenced in meaning by L *sollicitus* anxious), fr. L *sollicitare* to disturb, agitate, move, entreat, fr. *sollicitus* anxious, troubled, fr. *sollus* whole, entire (fr. Oscan; akin to Gk *holos* entire) + *citus*, past part. of *ciēre* to move — more at SAFE, HIGHT] *vt* 1 *archaic* a : to take charge or care of (as business) : MANAGE, FORWARD b : to act as solicitor or legal agent for or with reference to 2 *archaic* : to make anxious : DISQUIET, CONCERN 3 : to make petition to : ENTREAT, IMPORTUNE (~ the king for relief); *esp* : to approach with a request or plea (as in selling or begging) (~ one's neighbors for contributions) 4 : to move to action : serve as an urge or incentive to : INCITE 5 : to strongly urge (as one's cause or point) : insist upon 6 a : to entice or lead astray by or as if by specious arguments : lure on and esp. into evil b *obs* : to seek the favor of (a woman) usu. for the purpose of seduction : attempt to seduce c : to accost (a man) for immoral purposes and usu. in the character of a prostitute 7 : to endeavor to obtain by asking or pleading : plead for (~ an office) (~ alms); *also* : to seek eagerly or actively 8 : to demand as a requisite : call for : REQUIRE (the situation ~s the closest attention) 9 a (1) : to have an effect on (a person or thing) through some natural influence or property (2) : to induce (as a phenomenon) by means of such influence or property (~ing sparks by rubbing amber with flannel) b : to seek to affect (as by moving, inducing, withdrawing) usu. by mild or gentle means (~ a bowel movement with a laxative) (~ an arrow gently and draw it from a wound) 10 : to serve as a temptation or lure to : ATTRACT (that fruit . . . ~ed her longing eye —John Milton) ~ *vi* 1 : to make solicitation : IMPORTUNE, PETITION; as a : to beg alms b *of a prostitute* : to offer illicit intercourse to a man 2 : to serve as a solicitor *syn* see ASK

so·lic·i·tant \sə'lisəd·ənt, -sətənt\ *n* -s [L *sollicitant-*, *sollicitans*, pres. part. of *sollicitare* to solicit] : one who solicits

so·lic·i·ta·tion \sə,lisə'tāshən\ *n* -s [L *sollicitation-*, *sollicitatio*, fr. *sollicitatus* (past part. of *sollicitare*) + *-ion-*, *-io* -ion] 1 : the pursuit, practice, act, or an instance of soliciting; *often* : ENTREATY, IMPORTUNITY (yield to his ~s) 2 : the operation, influence, pressure, or other inducing effect of something that solicits or attracts or draws : a moving or drawing force : INCITEMENT, ALLUREMENT (unable to resist the ~s of appetite)

solicitor *n* -s [ME, fr. *soliciten* to solicit + *-er*] *obs* : SOLICITOR

so·lic·i·tor \sə'lisəd·ə(r), -isət-, *in rapid speech* 'sli-\ *n* -s [ME *solicitour*, fr. MF *soliciteur* prompter, agent, advocate, fr. *soliciter* to solicit, take care of] 1 : one that solicits; *esp* : a person that acts as an agent in the soliciting of something (as contributions to charity, subscriptions to periodicals, or business for a firm) 2 a (1) : a person formerly admitted to practice law in an English court of chancery or equity (2) : a person currently admitted to practice law and conduct litigation in any English court including the officers formerly called attorney-at-law and proctor but distinguished from the barrister in not having the right to plead in open court except in a few minor courts b : a law officer of a city, town, department, or government (the city ~) (the ~ of the Interior Department)

solicitor general *n, pl* **solicitors general** 1 : the second law officer in the government of Great Britain appointed to assist the attorney general 2 : an officer under the U.S. government appointed by the president to assist the attorney general 3 : the chief law officer in some states of the U.S.

so·lic·i·tor·ship \-,ship\ *n* : the position or status of a solicitor

so·lic·i·tous \sə'lisəd·əs, -is(ə)təs\ *adj* [L *sollicitus* — more at SOLICIT] 1 : full of concern or fears : APPREHENSIVE, TROUBLED, CONCERNED — often used with *about, for,* or *of* (~ about the future) (~ for the welfare of one's country) 2 : full of desire : anxiously willing : EAGER (~ to gain all the benefits) (not ~ to proceed in this affair) 3 : meticulously careful or attentive (~ in matters of dress) 4 : manifesting or expressing solicitude or concern (a ~ inquiry) — **so·lic·i·tous·ly** *adv* — **so·lic·i·tous·ness** *n* -es

so·lic·i·tress \-ə·trəs\ *n* -es [*solicitor* + *-ess*] : a female solicitor

solicitrix *n* -es [fr. *solicitor*, after such pairs as E *executor*: *executrix*] *obs* : a female solicitor

so·lic·i·tude \sə'lisə,tüd, -,tyüd\ *n* -s [ME, fr. MF or L; 1 ANXIETY, DISQUIETUDE (having few wants he had little cause for ~) (even the more peaceful hours . . . had beneath them a perpetual undercurrent of apprehensive ~ —Havelock Ellis) 2 a : urgently attentive care and sometimes excessive care and protectiveness (caring for the sick child with great ~) b : an attitude of solicitous concern or attention (inquired after her welfare with marked ~) 3 : a cause for or source of solicitude — usu. used in pl. (worn by the ~s of daily life) *syn* see CARE

so·lic·i·tu·di·nous \sə,lisə'tüd(ᵊ)nəs, -'tyüd-\ *adj* [L *sollicitudin-*, *sollicitudo* + E *-ous*] : marked by solicitude : SOLICITOUS

¹sol·id \'säləd\ *adj* -ER/-EST [ME *solide*, fr. MF, fr. L *solidus*; akin to Gk *holos*, entire — more at SAFE] 1 a : having an interior filled with matter : being without an internal cavity (the knob is heavy because it is ~) (the stalks of some plants are ~) (a ~ tire) — opposed to *hollow* b (1) : set in type without leads or other spacing material between the lines : CLOSE (a forbidding page full of ~ black paragraphs) (2) : having no intervening space (the ~ elements of a compound word) c : not interrupted by any break or opening (the outer walls ~ and windowless) (the law requires a driver to stay on his own side of the ~ line) 2 a : having or involving three dimensions : CUBIC (a ~ paraboloid) (a ~ foot contains 1728 ~ inches) b : of, relating to, or dealing with solid magnitudes (a ~ equation) — see SOLID GEOMETRY 3 a : marked by density or compactness : of uniformly close and coherent texture or consistency : not disintegrated, loose, or spongy (a ~ mass of rock) (rain fell in ~ sheets) (the surgeon scraped back to ~ healthy bone) b : possessing or characterized by the properties of a solid : being neither gaseous nor liquid (the pavement is not yet ~) (physics of the ~ state) 4 : of good and substantial quality or kind (~ comfort): as a : having merit or soundness (based his decision on ~ reasons) b : made firmly and well : STURDY (a ~ chair) (firm ~ walls) c (1) : full sounding and having a strong rhythmic drive (~ jazz music) (2) : excellent in every respect — used esp. of popular music d *of immunity* : capable of resisting severe challenge (intradermal inoculation of the virulent agent in guinea pigs resulted in ~ immunity in all trials) 5 : united or consolidated so as to form an integral whole: as a *of time* : having no break or interruption (stand for three ~ hours) b : UNANIMOUS (a ~ delegation) (the ~ vote of a delegation) (group opinion is ~) c : united or joined in intimacy : being on good terms — used with *with* (make oneself ~ with the chief) 6 a : having or marked by sound judgment or knowledge : thoroughly grounded (~ thinkers) (~ learning) b : SERIOUS-MINDED, RELIABLE, PRUDENT; *often* : well-established financially : having unimpaired credit (~ New Englanders) (the ~ men of the community) c : serious in purpose or character : not trivial : not vain or frivolous (time for ~ reading) 7 : entirely of one substance, formation, kind, or character: as a : entirely of one metal : containing the minimum of alloy necessary to impart hardness (~ gold) b : being or consisting of a single uniform color or tone c : having decorative details worked on solid material (a ~ frame) *syn* see FIRM

²solid \"\ *adv* : SOLIDLY; *often* : UNANIMOUSLY

³solid \"\ *n* -s [ME, fr. L *solidum*, fr. neut. of *solidus*, adj.] 1 : a magnitude that has the three dimensions length, breadth, and thickness : a part of space (as a cube, a sphere) bounded on all sides 2 a : a substance that does not flow perceptibly under moderate stress, has a definite capacity for resisting forces (as compression, tension, strain) which tend to deform it, and under ordinary conditions retains a definite size and shape — compare GAS, LIQUID b : material in solution or suspension that when freed of solvent or suspending medium has the form and qualities of a solid — usu. used in pl. (the ~s of the blood) (milk ~s include salts, protein, and sugar) — see SOLIDS-NOT-FAT 3 : something (as a substantial mass) that is solid: as a : a compact mass of masonry or comparable fabrication (as a wall or pier) as distinguished from one containing a void or an opening b : coal in place that has not been sheared, undercut, or similarly prepared for blasting c (1) : a solid color (2) : a printing plate having an entirely smooth surface without etching or design of any kind that is used for printing a solid color and esp. a tint (3) : one of the darkest or heaviest printing areas of a halftone as distinguished from middletone or highlight areas (4) : textile or other material of a solid color — usu. used in pl. d : a compound word whose members are joined together without a hyphen

sol·i·da·go \,sälə'dā(,)gō\ *n* [NL, fr. ML *soldago* an herb reputed to heal wounds, fr. *solidare* to make whole, make sound, fr. L *solidare*, fr. *solidus* solid] 1 *cap* : a very large genus of chiefly No. American herbs (family Compositae) that are distinguished from members of *Aster* by no definite characters but usu. have stems resembling wands, small heads with yellow or occas. white ray florets, and an inflorescence which varies from a thyrsoid panicle to axillary capitate clusters — see OVERT-WARS, GOLDENROD 2 -s : any plant of the genus *Solidago*

solid alcohol *n* : a product consisting of ordinary alcohol converted to a gel (as by means of a soap or calcium acetate) and used on a small scale as a fuel

solid angle *n* : the angular spread at the vertex of a cone or similar figure measured by the area intercepted on a unit sphere about the vertex as center by the cone surface

sol·i·dar·ic \,sälə'darik\ *adj* [*solidarity* + *-ic*] : having solidarity

sol·i·dar·i·ly \-dərəlē\ *adv* : in a solidary manner : so as to be solidary

sol·i·dar·ism \'sälədə,rizəm\ *n* -s [*solidarity* + *-ism*] 1 : SOLIDARITY 2 : a theory in sociology: the mutual interdependence of members of society offers a basis for a social organization based upon solidarity of interests

sol·i·dar·ist \-rəst\ *n* -s [*solidarity* + *-ist*] : an advocate of solidarism

sol·i·dar·is·tic \;==;ristik\ *adj* [*solidarist* + *-ic*] : of or relating to solidarity or solidarism : based on solidarism (~ concepts)

sol·i·dar·i·ty \,sälə'darəd·ē, -rətē, -i *also* -der-\ *n* -s [F *solidarité*, fr. *solidaire* solidary + *-ité* -ity] 1 : an entire union of interests and responsibilities in a group : community of interests, objectives, or standards (~ that knits together innumerable hearts —Joseph Conrad) 2 *Roman, civil, & Scots law* : the quality or state of being solidary

sol·i·dar·ize \'sälədə,rīz\ *vi* -ED/-ING/-S [F *solidariser*, fr. *solidaire* + *-iser* -ize] : to come together : attain a state of solidarity (the parties of the right failed to ~ in time)

sol·i·dary \'sälə,derē\ *adj* [F *solidaire*, fr. MF, fr. L (*in*) *solidum* for the whole, involving all (fr. *in* + *solidum* whole sum, fr. neut. of *solidus* solid) + MF *-aire* -ary — more at IN, SAFE] 1 : characterized by or manifesting community of interests and responsibilities 2 : constituting or relating to an obligation in solido under Roman, civil, or Scots law wherein the parties thereto are bound jointly and severally for the entire debt or damages or for the full performance or object of the obligation, or wherein any one party entitled to such an obligation may receive the full debt, damages, performance, or object of the obligations and give a receipt or release binding all others entitled thereto — compare CORREAL

solid board *n* : a paperboard made of the same type of material throughout — distinguished from *combination board*

solid box *n* : a solid ring bearing for a shaft that is lined with babbitt metal, is not adjustable, and is used esp. on light machinery

solid bull *n* : COMB

solid casting *n* : slip casting of ceramic material without pouring off of residue esp. for forming solid pieces or for hollow ware if the mold has a core

solid compound *n* : a compound whose components are solid in printing or writing — compare OPEN COMPOUND

solid die *n* : a hollow internally threaded screw-cutting tool made in one piece

solid-drawn \'=;=\ *adj* : drawn out from a hot solid bar esp. by a process of spiral rolling that first hollows the bar

soli Deo sit gloria to God alone be the glory; fr. the fact that it is removed only on approaching the sanctuary] : ZUCCHETTO

solider *comparative of* SOLID

solidest *superlative of* SOLID

solid geometry *n* : a branch of geometry that deals with the figures of three-dimensional space

solid hoof *n* : a hoof (as of a horse) that forms a continuous encasement of the distal part of a foot — compare CLOVEN FOOT

solid-hoofed \';=;=\ *adj* [*solid hoof* + *-ed*] 1 : SOLIDUNGULATE 2 : MULE-FOOT

solidi *pl of* SOLIDUS

so·lid·i·fi·able \sə'lidə,fīəbəl, ·,··'···\ *adj* : capable of being solidified

so·lid·i·fi·ca·tion \sə,lidəfə'kāshən\ *n* -s [fr. *solidify*, after such pairs as E *ratify*: *ratification*] 1 : an act or instance of solidifying 2 : the condition of being solidified

so·lid·i·fi·er \-·,fī(ə)r, -īə\ *n* -s : one that solidifies

so·lid·i·fy \sə'lidə,fī\ *vb* -ED/-ING/-ES ['*solid* + *-fy*] *vt* : to make solid or compact or hard: as a : to alter (a fluid) to a solid state (~ concrete) b : to give a feeling of reality to (details that *solidified* the composition) c : to cause to take on strength and assurance (~*ing* one's knowledge) : make secure, substantial, or firmly fixed (factors that ~ public opinion) ~ *vi* : to become solid : HARDEN (hot paraffin *solidifies* as it cools)

solid injection *n* : the injection of atomized fuel oil into the combustion chamber of a diesel engine under the pressure of the liquid fuel itself — compare AIR INJECTION

sol·id·ish \'säladish\ *adj* : comparatively solid

so·lid·i·ty \sə'lidəd·ē, -idətē, -i\ *n* -es [MF *solidité*, fr. L *soliditat-*, *soliditas*, fr. *solidus* solid + *-itat-*, *-itas* -ity] 1 : the quality or state of being solid : lack of an interior cavity : DENSITY, COMPACTNESS (stone oppressed him with its indestructible ~ —Aldous Huxley) (felt the rubbery ~ as the club came down —Ernest Hemingway) 2 : the quality or character (as in a human being, act, institution) of being sound in a moral, mental, financial, or other comparable respect 3 : something solid : a solid body 4 *archaic* : space within a closed surface : VOLUME 5 : the ratio of the projected area of the blades of a rotor to the area swept by the blades

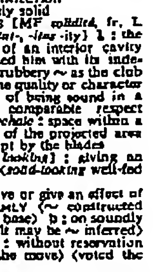
solid-looking \'==,==\ *adj* ['*solid* + *looking*] : giving an impression of solid worth or substance (*solid-looking* well-fed citizens)

sol·id·ly *adv* ['*solid* + *-ly*] : so as to have or give an effect of solidity: as a (1) : STRONGLY, FIRMLY (~ constructed furniture) (2) : SECURELY (set ~ on its base) b : on soundly logical or reasonable grounds (the result may be ~ inferred) c *archaic* : SERIOUSLY, INTENSIVELY d : without reservation : WHOLLY, UNANIMOUSLY (~ behind the move) (voted the precinct ~ for the party candidate)

solid-mouth \'==,=\ *also* **solid-mouthed** \';=;=\ *adj, of a sheep* : having a complete set of teeth — compare BROKEN-MOUTHED

sol·id·ness *n* -ES : the quality or state of being solid

solid newel *n* : a newel into which the ends of winding stairs are built — distinguished from *hollow newel*



solid newel

solid of revolution ['*solid*] : a mathematical solid conceived as formed by the revolution of a plane figure about an axis in its plane

solids *pl of* SOLID

solids-not-fat \';==,=\ *n pl but usu sing in constr* : the constituents of milk other than butterfat and water (*solids-not-fat* is lowest in summer)

solid solution *n* ['*solid*] : a homogeneous solid phase (as austenite) capable of existing throughout a range of chemical composition — used chiefly of crystalline materials; often distinguished from *intermetallic compound*; compare MIXTURE

solid system *n* : an underground electrical distribution system in which the conductors or cables are buried rather than pulled into ducts

sol·i·dum \'sälədəm\ *n* -s [L, neut. of *solidus* solid] 1 : the dado of a pedestal 2 : an entire sum : WHOLE — used in various phrases (as *in solidum*, *singuli in solidum*)

sol·id·un·gu·la \,sälə'dəŋgyələ\ *n pl, cap* [NL, fr. L *solidus* + *ungula* hoof — more at UNGULA] *in some classifications* : a group coextensive with Hippoidea

sol·id·un·gu·lar \;==;==lə(r)\ *also* **sol·id·un·gu·lous** \-ləs\ *adj* [L *solidus* solid + *ungula* hoof + E *-ar*, *-ous*] : SOLIDUNGULATE

¹sol·id·un·gu·late \-lət, -,lāt\ *adj* [L *solidus* solid + *ungula* hoof + E *-ate*] : having a single hoof on each foot (horses and other ~ mammals)

²solidungulate \"\ *n* -s : a solidungulate animal

sol·i·dus \'sälədəs\ *n, pl* **soli·di** \-,dī\ [ME, fr. LL, fr. L *solidus* solid — more at SAFE] 1 : an ancient Roman gold coin introduced by Constantine as successor to the aureus and used until the fall of the Byzantine Empire 2 [ML *solidus* shilling, fr. LL, a gold coin; fr. its use as a symbol for shillings] : DIAGONAL 4 3 a *also* **solidus curve** [L, solid, adj.] : a curve usu. on a temperature-composition diagram for a binary system that corresponds with a liquidus and that indicates temperatures below which only the solid phase can exist b *also* **solidus point** : the point of temperature at which a substance and esp. a metal or alloy is about to melt : incipient melting point

so·lier·i·a·ce·ae \sō,lirē'āsē,ē\ *n pl, cap* [NL, fr. *Solieria* genus of algae + *-aceae*] : a family of red algae (order Gigartinales) having multiaxial thalli and inhabiting the warmer seas

sol·i·fid·i·an \,sälə'fidēən, ,sōl-\ *n* -s [*soli-* + L *fides* faith + E *-ian* — more at FAITH] : one who holds that faith alone without achievement or personal merit is sufficient to insure salvation — compare NULLIFIDIAN

sol·i·fid·i·an·ism \-ē,nizəm\ *n* -s : the doctrine of the solifidians

soli·fluction *also* **soli·fluxion** \;sōlə, ;sälə+\ *n* -s [L *solum* ground, soil + *-i-* + *fluction-*, *fluctio* act of flowing, fr. *fluctus* (past part. of *fluere* to flow) + *-ion-*, *-io* -ion — more at FLUID] : the slow creeping of wet soil and other saturated fragmental material down a slope resulting sometimes in the formation of small terraces : the selective movement of soil particles and rock waste in regions of perennially frozen ground by frost action and associated phenomena producing soil structures of various kinds and shapes — compare CONGELITURBATION — **soli·fluctional** \"+\ *adj*

so·lif·u·gae \sə'lifyə,jē\ [NL, fr. pl. of LL *solifuga*, a venomous ant or spider, alter. of L *salpuga*] *syn of* SOLPUGIDA

soli·fuge \'sälə,fyüj, 'sōl-\ *n* -s [LL *solifuga*] : SOLPUGID

so·lif·u·ge·an \sə,lifyə'jēən\ *or* **so·lif·u·gous** \-'lifyəgəs\ *adj* [LL *solifuga* + E *-ean* or *-ous*] : SOLPUGID

so·lif·u·gid \-'lifyəjəd\ *n* -s [NL *Solifugae* + E *-id*] : SOLPUGID

so·lig·e·nous \sə'lijənəs\ *adj* [L *solum* ground + E *-i-* + *-genous*] : produced by inflow of surface water or rise of ground water and not by locally precipitated water (a ~ marsh)

so·lil·o·quist \sə'liləkwəst\ *n* -s [*soliloquy* + *-ist*] : one who soliloquizes

so·lil·o·quize \sə'lilə,kwīz\ *vb* -ED/-ING/-S *see* -IZE *in Explan Notes* [*soliloquy* + *-ize*] *vi* : to utter a soliloquy : talk to oneself ~ *vt* : to say, discuss, or address in a soliloquy — **so·lil·o·quiz·er** \-zə(r)\ *n* -s

so·lil·o·quiz·ing·ly \·'·····, ·,··'···\ *adv* [*soliloquizing* (pres. part. of *soliloquize*) + *-ly*] : in the manner of one that soliloquizes

so·lil·o·quy \sə'liləkwē, -wi\ *n* -es [LL *soliloquium*, fr. L *soli-* + *loqui* to speak] 1 : the act of talking to oneself : a discourse made by one in solitude to oneself : MONOLOGUE 2 : a poem, a discourse, or an utterance of a dramatic character that has the form of a monologue or gives the illusion of being a series of unspoken reflections

+ *-iner* — more at

United States Patent [19]
Nesbitt

[11] **4,431,193**
[45] **Feb. 14, 1984**

[54] **GOLF BALL AND METHOD OF MAKING SAME**

[75] Inventor: **R. Dennis Nesbitt**, Westfield, Mass.

[73] Assignee: **Questor Corporation**, Tampa, Fla.

[21] Appl. No.: **296,146**

[22] Filed: **Aug. 25, 1981**

[51] Int. Cl.³ **A63B 37/12**
[52] U.S. Cl. .... **273/235 R; 273/218; 273/DIG. 22**
[58] Field of Search .... 273/235 R, 225, 218, 273/214, 217, DIG. 8, DIG. 22

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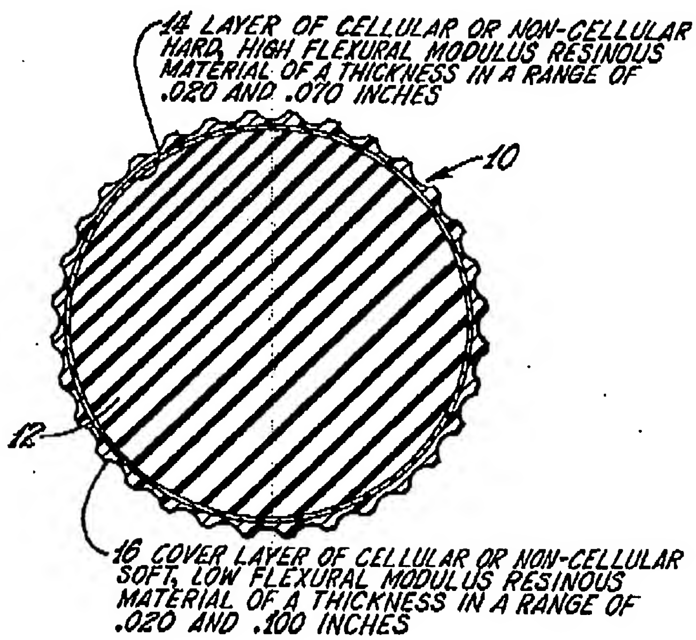
4,274,637	6/1981	Molitor	273/DIG. 8 X

Primary Examiner—George J. Marlo
Attorney, Agent, or Firm—Harry O. Ernsberger; Donald R. Bahr

[57] **ABSTRACT**

The disclosure embraces a golf ball and method of making same wherein the golf ball has a solid (not thread-wound) resilient center or core, and a multilayer cover construction which involves a first layer or ply of molded hard, high flexural modulus resinous material on the core, and a second or cover layer of soft, low flexural modulus resinous material molded over the first layer to form a finished golf ball. The first layer is of a thickness in a range of 0.020 inches and 0.070 inches and may be of resinous material such as Type 1605 Surlyn marketed by E. I. du Pont de Nemours and Company, and the second or cover layer is of a thickness in a range of 0.020 inches and 0.100 inches and may be of resinous material such as Type 1855 Surlyn marketed by E. I. du Pont de Nemours and Company. Foamable materials for producing a cellular first layer or cellular cover layer are polymeric materials such as ionomer resins.

13 Claims, 2 Drawing Figures



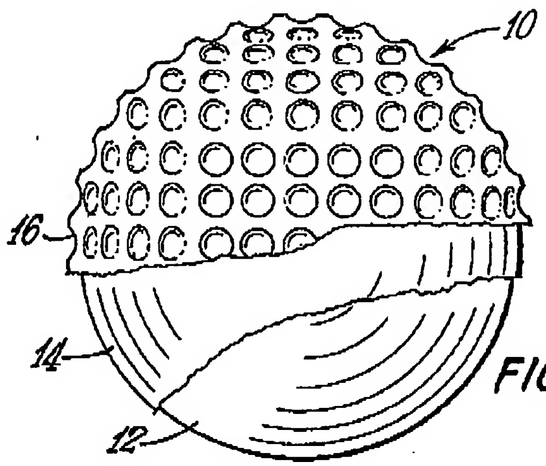

10
16
14
12

FIG. 1

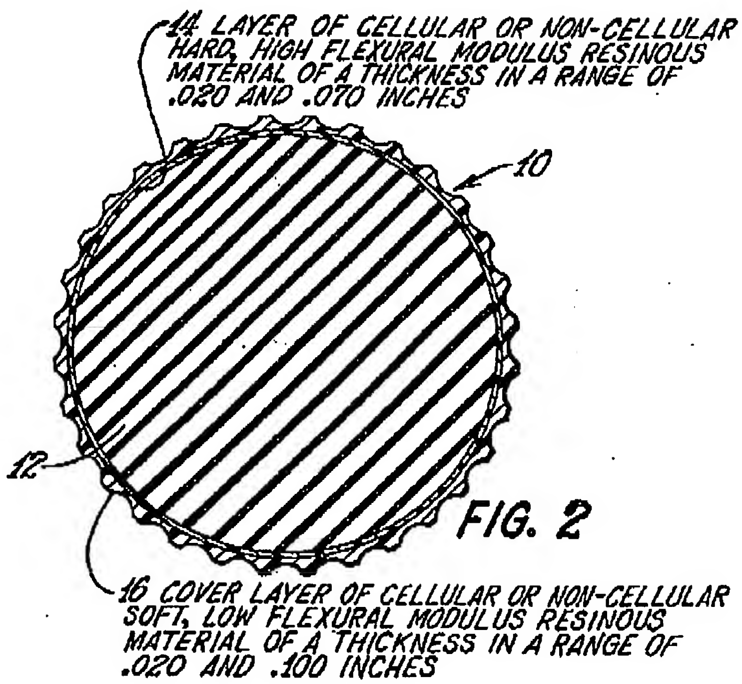

14 LAYER OF CELLULAR OR NON-CELLULAR HARD, HIGH FLEXURAL MODULUS RESINOUS MATERIAL OF A THICKNESS IN A RANGE OF .020 AND .070 INCHES
10
12
16 COVER LAYER OF CELLULAR OR NON-CELLULAR SOFT, LOW FLEXURAL MODULUS RESINOUS MATERIAL OF A THICKNESS IN A RANGE OF .020 AND .100 INCHES

FIG. 2

GOLF BALL AND METHOD OF MAKING SAME

TECHNICAL FIELD

The invention relates to a golf ball and more particularly to a cover construction for a golf ball.

BACKGROUND ART

Golf balls having a cover material marketed under the trademark "Surlyn" by E. I. du Pont de Nemours and Company of Wilmington, Del., are known in the art and such cover compositions generally comprise a copolymer of an olefin and at least one unsaturated monocarboxylic acid. Conventional two-piece golf balls are comprised of a solid resilient center or core with molded Surlyn covers. The cover used is normally a hard, high flexural modulus Surlyn resin in order to produce a gain in the coefficient of restitution over that of the center or core.

In a conventional two-piece golf ball, a hard, high flexural modulus Surlyn resin is molded over a resilient center or core. The hard, highly flexural modulus Surlyn resin for the cover of a two-piece golf ball is desirable as it develops the greatest hoop stress and consequently the greatest coefficient of restitution.

A two-piece golf ball having a hard, Surlyn resin cover however does not have the "feel" or playing characteristics associated with softer balata covered golf balls. Heretofore balata covered golf balls have been preferred by most golf professionals. If a golf ball has a cover of soft, low flexural modulus Surlyn resin molded directly over a center or core, it is found that little or no gain in coefficient of restitution is obtained.

DISCLOSURE OF THE INVENTION

In accordance with the present invention there is provided a golf ball having a multilayer or two-ply cover construction for a solid resilient center or core wherein the multilayer cover construction involves two stage molded cover compositions over a solid center or core of resilient polymeric material wherein an increased coefficient of restitution is attained and wherein the "feel" or playing characteristics are attained similar to those derived from a balata covered golf ball.

The invention embraces a golf ball and method of making same wherein the ball has a solid center or core of resilient polymeric or similar material covered by a first layer or ply of molded hard, highly flexural modulus resinous material or of cellular or foam composition which has a high coefficient of restitution.

The first layer or ply is provided with a second or cover layer of a comparatively soft, low flexural modulus resinous material or of cellular or foam composition molded over the first layer and core or center assembly. Such golf ball has the "feel" and playing characteristics simulating those of a softer balata covered golf ball.

Through the use of the first ply or layer of hard, high flexural modulus resinous material on the core or center, a maximum coefficient of restitution may be attained. The resinous material for the first ply or layer may be one type of Surlyn marketed by E. I. du Pont de Nemours and Company of Wilmington, Del., and the other ply or cover layer may be of a different type of Surlyn resin also marketed by the same company.

The three-piece golf ball of the invention provides a golf ball in which the coefficient of restitution of the golf ball closely approaches or attains that which provides the maximum initial velocity permitted by the United States Golf Association Rules of two hundred fifty feet per second with a maximum tolerance of two percent, which velocity may be readily attained and the playing characteristics or "feel" associated with a balata covered ball secured while maintaining a total weight of the golf ball not exceeding 1.620 ounces without sacrificing any advantages of a golf ball having a standard Surlyn cover of the prior art or a golf ball having a softer balata cover.

Further objects and advantages are within the scope of this invention such as relate to the arrangement, operation and function of the related elements of the structure, to various details of construction and to combinations of parts, elements per se, and to economies of manufacture and numerous other features as will be apparent from a consideration of the specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The details of the invention will be described in connection with the accompanying drawings in which:

FIG. 1 is a view of a golf ball embodying the invention illustrating portions of the multiply or multilayer cover construction on a core or center, and

FIG. 2 is a diametrical cross sectional view of the golf ball of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to the drawings in detail there is illustrated a golf ball 10 which comprises a solid center or core 12 formed as a solid body of resilient polymeric material or rubber-like material in the shape of a sphere. Disposed on the spherical center or core 12 is a first layer, lamination, ply or inner cover 14 of molded hard, highly flexural modulus resinous material such as type 1605 Surlyn marketed by E. I. du Pont de Nemours and Company, Wilmington, Del.

This material of the inner layer 14 being a hard, high flexural modulus resin produces a substantial gain of coefficient of restitution over the coefficient of restitution of the core or center. An outer layer, ply, lamination or cover 16 of comparatively soft, low flexural modulus resinous material such as type 1855 Surlyn marketed by E. I. du Pont de Nemours and Company is then re-molded onto the inner ply or layer 14, the outer surface of the outer layer or cover 16 being of dimpled configuration providing a finished three-piece golf ball.

According to the United States Golf Association Rules, the minimum diameter prescribed for a golf ball is 1.680 inches and the maximum weight prescribed for a golf ball is 1.620 ounces. It is therefore desirable to produce a golf ball having an improved coefficient of restitution to attain an initial velocity for the golf ball approaching the maximum velocity limit of 255 feet per second, the maximum limit provided by the United States Golf Association Rules.

The hard, high flexural modulus resin is employed to increase the coefficient of restitution in order to attain or approach the maximum initial velocity for the golf ball. The use of a soft low flexural modulus resin provides little or no gain in the coefficient of restitution and may tend to reduce the coefficient of restitution thereby adversely affecting the initial velocity factor.

In producing the golf ball of the invention, the density of the center or core may be varied and the relative thicknesses of the layers, plies or laminations 14 and 16

may be varied within limits so that the golf ball weight does not exceed 1.620 ounces, the minimum diameter not less than 1.680 inches, and the ball be capable of an initial velocity approaching 255 feet per second. However, the finished golf ball may be of larger diameter providing the total weight of the ball does not exceed 1.620 ounces.

Thus, by varying the density of the center or core 12 and varying the thicknesses of the plies or layers 14 and 16 of the cover construction, a golf ball may be produced having a total weight not exceeding 1.620 ounces and a minimum diameter of 1.680 inches and having a comparatively high coefficient of restitution, the ball closely approaching or attaining in play the maximum permitted initial velocity of 255 feet per second.

In the golf ball of the invention the thickness of the inner layer or ply 14 and the thickness of the outer layer or ply 16 may be varied to secure the advantages herein mentioned. It is found that the inner layer 14 of hard, high flexural modulus resinous material, such as Surlyn resin type 1605, is preferably of a thickness in a range of 0.020 inches and 0.070 inches. The thickness of the outer layer or cover 16 of soft, low flexural modulus resin, such as Surlyn type 1855, may be in a range of 0.020 inches and 0.100 inches.

For example, a center or core 12 having a 0.770 coefficient of restitution is molded with a layer of hard, high modulus Surlyn resin, such as Surlyn type 1605, to form a spherical body of a diameter of about 1.565 inches. This spherical body comprising the core or center 12 and layer 14 of the hard, high modulus Surlyn resin has a coefficient of restitution of 0.800 or more.

This center or core 12 and inner layer 14 of hard resinous material in the form of a sphere is then remolded into a dimpled golf ball of a diameter of 1.680 inches minimum with an outer or cover layer 16 of a soft, low flexural modulus resin such as Surlyn type 1855. The outer layer of the soft resin is of a thickness of 0.0575 inches. The soft Surlyn resin cover would have about the same thickness and shore hardness of a balata covered golf ball and would have the advantageous "feel" and playing characteristics of a balata covered golf ball.

It is to be understood that the golf ball of the invention may be made of a diameter greater than 1.680 inches without exceeding the total weight of 1.620 ounces by varying the thickness of the inner layer or ply 14 and the outer cover layer or ply 16 and secure desired "feel" and playing characteristics.

The inner, intermediate, or first layer or ply 14 and the outer cover, second layer or ply 16 or either of the layers may be cellular when formed of a foamed natural or synthetic polymeric material. Polymeric materials are preferably such as ionomer resins which are foamable. Reference is made to the application Ser. No. 155,658, of Robert P. Molitor issued into U.S. Pat. No. 4,274,637 which describes a number of foamable compositions of a character which may be employed for one or both layers 14 and 16 for the golf ball of this invention.

The inner, intermediate or first layer 14 on the core 12 may be preferably partially or only slightly foamed to a low degree so as not to materially affect the coefficient of restitution of the material. The outer or cover layer or second layer 16 may be foamed to a greater degree than the inner, intermediate or first layer 14 as the material of the layer 16 is comparatively soft.

The inner, intermediate or first layer 14 may be unfoamed or noncellular and the outer layer may be cellular or foamed resin. If certain characteristics are desired for the golf ball, the inner layer 14 may be slightly or partially foamed and the outer or cover layer or ply 16 may be of unfoamed or noncellular material.

Through the use of foamable material for the first layer, the cover layer or both layers, the degree of foaming of one or the other or both layers may be altered to provide a variation in the coefficient of restitution of the golf ball.

It is apparent that, within the scope of the invention, modifications and different arrangements may be made other than as herein disclosed, and the present disclosure is illustrative merely, the invention comprehending all variations thereof.

I claim:

1. A golf ball comprising a spherically-shaped solid core of resilient material, a first layer of hard, high flexural modulus ionomer resin molded onto the core, and a cover layer of soft, low flexural modulus ionomer resin molded over the first layer of ionomer resin on the core, the total weight of the golf ball not exceeding 1.620 ounces.

2. A golf ball comprising a spherically-shaped solid core of resilient polymeric material, a first layer of hard, high flexural modulus ionomer resin molded onto the core, and a second layer of soft, low flexural modulus ionomer resin molded over the first layer of ionomer resin on the core, the total weight of the golf ball not exceeding 1.620 ounces.

3. A golf ball comprising a spherically-shaped solid core of resilient polymeric material, a layer of comparatively hard, high flexural modulus ionomer resin molded onto the core, the exterior surface of the layer being of spherical configuration, and a cover layer of comparatively soft, low flexural modulus ionomer resin molded over the layer of hard, high flexural modulus ionomer resin, the outer surface of the cover layer being of dimpled configuration, the total weight of the golf ball not exceeding 1.620 ounces.

4. A golf ball comprising a spherically-shaped solid core of resilient material, a hard, high flexural modulus ionomer resin molded onto the core forming a layer on the core, a soft, low flexural modulus ionomer resin molded over the layer of high flexural modulus ionomer resin providing a cover layer of generally spherical shape, the exterior surface of said cover layer being of dimpled configuration, the total weight of the golf ball not exceeding 1.620 ounces, and the diameter of the golf ball being not less than 1.680 inches.

5. A golf ball according to claim 4 wherein the layer of hard, high flexural modulus ionomer resin is of a thickness in a range of 0.020 inches and 0.070 inches.

6. A golf ball according to claim 4 wherein the cover layer of soft, low flexural modulus ionomer resin is of a thickness in a range of 0.020 inches and 0.100 inches.

7. A three-piece golf ball comprising a spherically-shaped solid core of resilient material, a comparatively hard, high flexural modulus ionomer resin molded onto the core forming a layer of the hard, high flexural modulus ionomer resin on the core, and a comparatively soft, low flexural modulus ionomer resin molded onto the layer of hard, high flexural modulus ionomer resin forming a cover layer, the exterior surface of the cover layer being a dimpled configuration and generally of spherical shape, the total weight of the golf ball not

exceeding 1.620 ounces, and the diameter of the golf ball being not less than 1.680 inches.

8. A three-piece golf ball comprising a spherically-shaped solid core of resilient material, a hard, high flexural modulus surlyn resin molded onto the core forming a first layer of spherical configuration on the core, a soft, low flexural modulus SURLYN resin molded over the first layer of hard, high flexural modulus SURLYN resin to form a cover layer of spherical configuration, the exterior surface of the cover layer being of dimpled configuration, and the total weight of the golf ball not exceeding 1.620 ounces.

9. A golf ball comprising a spherically-shaped solid core of resilient material, a first layer of hard, high flexural modulus ionomer resin molded onto the core, and a cover layer of soft, low flexural modulus foamable ionomer resin molded over the first layer of ionomer resin on the core, said cover layer being foamed to a cellular condition, the total weight of the ball not exceeding 1.620 ounces.

10. A golf ball comprising a spherically-shaped solid core of resilient material, a first layer of hard, high flexural modulus foamable ionomer resin molded onto the core, said first layer being foamed to a cellular condition, and a cover layer of soft, low flexural modulus ionomer resin molded over the first layer of foamable ionomer resin on the core, the total weight of the ball not exceeding 1.620 ounces.

11. A golf ball comprising a spherically-molded solid core of resilient material, a first layer of hard, high flexural modulus foamable ionomer resin molded onto the core, said first layer being foamed to a cellular condition, and a cover layer of soft, low flexural modulus foamable ionomer resin molded over the first layer of ionomer resin, said cover layer being foamed to a cellular condition, the total weight of the ball not exceeding 1.620 ounces.

12. The method of producing a three-piece golf ball including providing a solid core of resilient material of spherical configuration, molding onto the core a hard, high flexural modulus ionomer resin providing a first layer on the core, molding a soft, low flexural modulus ionomer resin onto the first layer providing a cover layer of spherical shaped wherein the total weight of the golf ball does not exceed 1.620 ounces and the ball being of a diameter not less than 1.680 inches.

13. The method of producing a three-piece golf ball including providing a solid core of resilient polymeric material of spherical configuration, molding onto the core a hard, high flexural modulus SURLYN resin providing a first layer on the core, molding a soft, low flexural modulus Surlyn resin onto the first layer providing a cover layer of spherical shape wherein the total weight of the golf ball does not exceed 1.620 ounces and the ball being of a diameter not less than 1.680 inches.

* * * * *

United States Patent [19]
Prewett et al.

[11] **4,431,137**
[45] **Feb. 14, 1984**

[54] **SOURCES FOR SPRAYING LIQUID METALS**

[75] Inventors: **Philip D. Prewett**, Abingdon; **Leonard Gowland**, Grove; **Keith L. Aitken**, Kennington, all of England

[73] Assignee: **United Kingdom Atomic Energy Authority**, London, England

[21] Appl. No.: 438,912

[22] Filed: Nov. 3, 1982

Related U.S. Application Data

[63] Continuation of Ser. No. 177,451, Aug. 12, 1980, abandoned.

[30] **Foreign Application Priority Data**

Aug. 23, 1979 [GB] United Kingdom 7929361

[51] Int. Cl.^{3} B05B 5/00

[52] U.S. Cl. .... 239/690; 239/590; 118/302; 75/0.5 C

[58] Field of Search .... 239/3, 82, 504, 542, 239/590, 598, 601, 690, 697, 698, 708, DIG. 19, 620, 627; 118/302; 427/422; 313/333, 362, 232, 163; 75/0.05 C, 0.05 A

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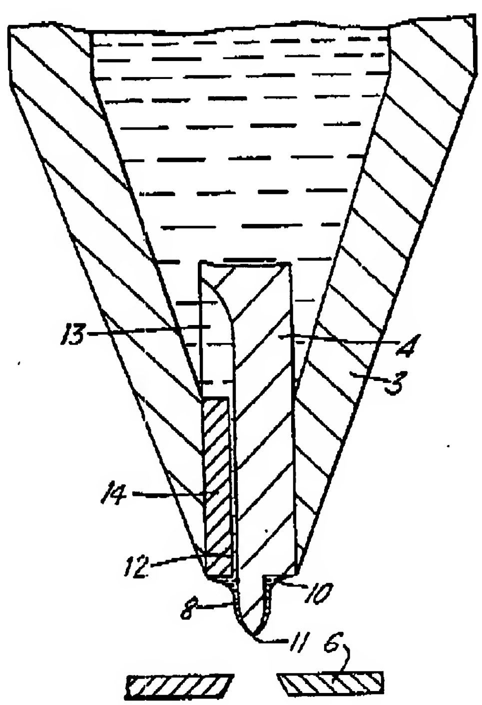
Primary Examiner—John J. Love
Assistant Examiner—Paul A. Sobel
Attorney, Agent, or Firm—William R. Hinds

[57] **ABSTRACT**

A source for producing a spray of drops and ions of a liquid material under the action of an electric field, comprises an emitting point in the shape of a cone with a rounded tip, the vertex angle of which is between thirty and forty degrees and which projects beyond a base structure by a distance of between some one and three millimeters, means for supplying a liquid material to be sprayed to the emitting point and a field generating electrode whereby there may be applied to the emitting point an electric field sufficient to disrupt the liquid material at the emitting point and provide a spray of liquid drops and ions, the emitting point being made of a material which is wetted by the liquid material and has a low solubility in the liquid material.

16 Claims, 4 Drawing Figures



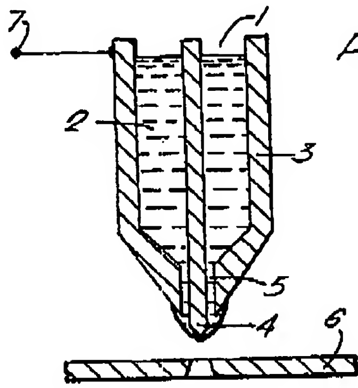


Fig. 1.

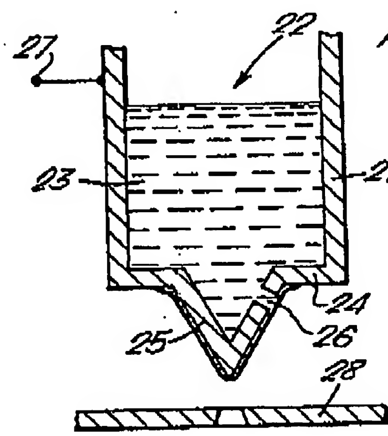


Fig. 3.

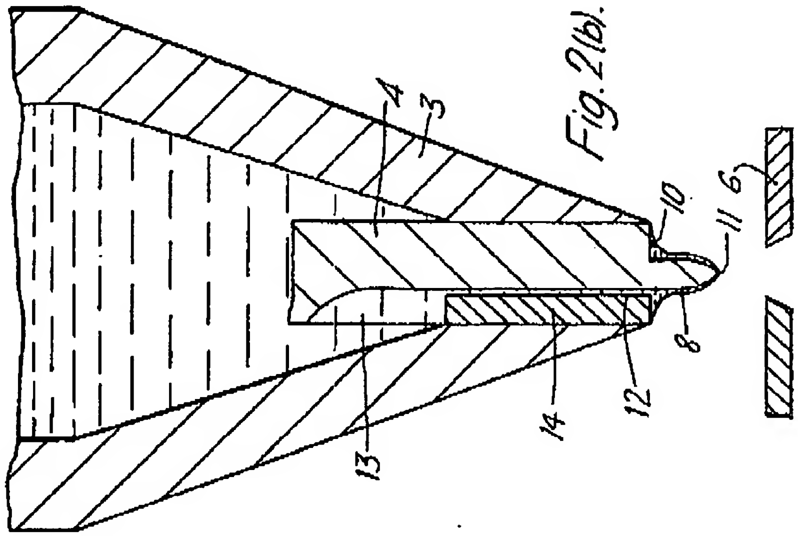


Fig. 2(b).

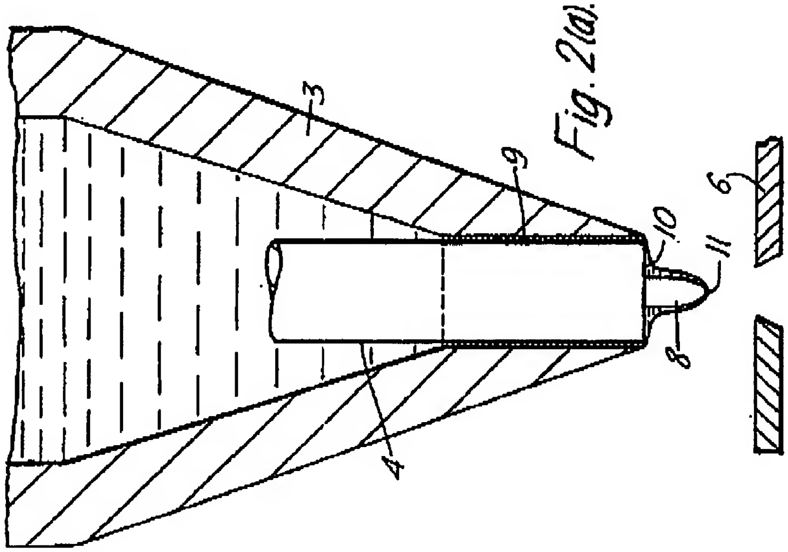


Fig. 2(a).

SOURCES FOR SPRAYING LIQUID METALS

This is a continuation of application Ser. No. 177,451 filed Aug. 12, 1980, now abandoned.

The present invention relates to sources for the spraying of liquid metals.

The deposition of metallic coatings by means of sprays of ions or small droplets formed by field emission from pointed needles is a known technique. Types of sources of metal droplets and ions are described in our UK Pat. No. 1,442,998 and Applications Nos. 15111/76 and 30722/77. Whether ions or droplets are produced by a given source is dependent mainly upon the dimensions and shape of the source and upon the strength of the applied electric field.

According to the present invention there is provided a source for producing a spray of drops and ions of a liquid material under the action of an electric field, comprising an emitting point in the shape of a cone with a rounded tip, the vertex angle of which is between thirty and forty degrees and which projects beyond a base structure by a distance of one to three millimetres, means for supplying a liquid material to be sprayed to the emitting point, and a field generating electrode whereby there may be applied to the emitting point an electric field sufficient to disrupt the liquid material at the emitting point and provide a spray of liquid drops and ions, the emitting point being made of a material which is wetted by the liquid material and has a low solubility in the liquid material.

The invention will be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 shows a diagrammatic longitudinal section of a source embodying the invention; and

FIGS. 2(*a*) and 2(*b*) show diagrammatic longitudinal sections of preferred embodiments for the spraying of gold and gold alloys; and

FIG. 3 shows a diagrammatic longitudinal section of another embodiment of the invention.

Referring to FIG. 1, a source for producing a spray of liquid metal drops consists of a reservoir 1 for the liquid metal 2, which terminates in a hollow cylindrical base structure 3 some 7 mm in outside diameter. The internal diameter of the base structure 3 is some 5 mm reducing to some 0.5 mm. Centrally placed in the base structure 3 is an emitting point 4 which projects some one to three mm from the end of the base structure 3. The diameter of the emitting point 4 is 25 μm less than the hole 5 in the centre of the base structure 3. Both the spraying tip of the emitting point 4 and the end of the base structure 3 are conical in shape with a vertex angle of 35°, although angles of 30 and 40 degrees are satisfactory. The emitting point 4 has a tip radius of between 20μ and 100μ depending upon the proportion of droplets required in the spray. For a given voltage, a tip of smaller radius will produce a higher ratio of ions to droplets than a blunter emitting tip. The most suitable value of tip radius for most coating applications is some 60 μm.

An electric field sufficient to disrupt the film of liquid metal which forms over the emitting point 4 can be applied to the source by means of an extraction electrode 6 which is usually a circular aperture some 2 to 5 mm in diameter, and a terminal shown schematically at 7. If the source needs to be heated to maintain the metal to be sprayed in the liquid state, this can be done either by means of an electrically heated filament (not shown) surrounding the reservoir and base structure or by any other convenient method. The rate of feed of liquid to the emitting point 4 is controlled by surface forces, by the applied electric field and by viscous drag effects, together with gravity.

Alternatively, in this form of the embodiment, the base structure 3 may be made of a material, the outside of which is not wetted by the liquid metal. This may be necessary in some instances to prevent flooding of the emitting point 4 by an excess of liquid metal.

This is the case for the spraying of gold and gold alloys, a preferred embodiment for which is shown in FIG. 2(*a*). The base structure 3 is made from carbon which is not wetted by gold, the emitting point 4 is made of a tungsten wire of 1.6 millimeters diameter, reducing to 0.5 millimeters diameter over a portion 8 some one to three millimeters long which protrudes beyond the end of the base structure 3. The hole 5 in the base structure 3 has a diameter of some 1.8 to 2.0 millimeters. The gap between the wire 4 and the base structure 3 is filled by a tightly wound spiral 9 of tungsten wire of 0.1 millimeters diameter. The spiral 9 provides a capillary route along which the liquid metal flows to form a meniscus at the shoulder 10 formed by the junction between the main part of the emitting point 4 and the reduced portion 8 of the emitting point 4, and thence over the surface of the reduced portion 8 of the emitting point 4 to the spraying tip 11 from which it is removed in the form of droplets and ions by the action of the applied electric field.

The presence of the spiral 9 and the shoulder 10 produced by the reduction in diameter of the wire is fundamental to the formation of the liquid meniscus in this region in the absence of a wetted base structure 3. An adequate flow of liquid from the shoulder at 10 over the reduced portion 8 of the emitting point 4 is ensured by the provision of meridinal grooves, not shown, on the surface of the conical end of the emitting point 4, which forms the spraying tip 11.

Microscopic observation of the sprayer during operation has confirmed our model of the sprayer behaviour which is, referring again to FIG. 2(*a*) as follows:

Liquid metal is fed by a combination of gravity and surface wetting forces from the reservoir through the spiral controlling region 9 to form the meniscus on the shoulder region 10. As the voltage is increased, the loss of material from the spraying tip 11 increases. This loss must be supplied by flow from the shoulder 10 along the reduced length 8 of the emitting point 4. An adequate supply of liquid will be maintained only if there are sufficient continuous liquid paths between the shoulder 10 and the spraying tip 11. This is the reason for the fine meridinal grooves. At operating currents of some 60 μA or more when the emission of metal from the spraying tip 11 is relatively large, the meniscus surface at the shoulder 10 is seen to withdraw along the shank of the reduced portion 8 of the emitting point 4 and assumes a profile which, at equilibrium, closely follows the underlying topography of the emitting point 4. At currents of some 20 μA when the emission from the spraying tip 11 is much smaller, being chiefly composed of ions with relatively few droplets, the meniscus surface resumes a profile which is proud of the needle topography in the region of the shoulder 10. If the source is operated for prolonged periods in this low current regime, the point on the meniscus at which it blends into the underlying needle structure moves closer and closer to the spraying tip 11. Under extreme conditions, a Taylor cone can be

formed and the needle structure is lost from view, being completely submerged by the liquid meniscus of the sprayer which is then said to be 'flooded'. The source behaviour may be summarized as follows, referring to FIG. 2(*a*).

1. Flow to the meniscus is controlled by the spiral 9 and during normal operation depends only weakly upon the applied field.
2. The meniscus at the shoulder 10 acts as an intermediate reservoir the size and shape of which varies with the emission rate from the spraying tip 11.
3. All material emitted by the source (other than evaporation of atoms which occurs from all exposed liquid surfaces) occurs from the spraying tip 11, the rate of emission being determined by the magnitude of the field applied in this region.
4. Material emitted in this way is provided by flow along meridianal grooves from the meniscus at the shoulder 10, which changes in size and shape accordingly.
5. The electrical forces which determine the flow from the shoulder 10 to the spraying tip 11 act at the spraying tip 11, being coupled to the shoulder 10 by continuity in the incompressible liquid film which joins the shoulder 10 to the spraying tip 11. Electrical forces in the region of the shoulder 10 usually are relatively insignificant.

An alternative to the spiral flow control arrangement may be used in another embodiment of the sprayer which is shown schematically in FIG. 2(*b*). In this embodiment, the flow channel between reservoir and meniscus is a narrow capillary 12 of 0.05 mm square section extending for some 3 mm from the reservoir, to emerge at the corner where the shoulder 10 of the emitting point 4 meets the reduced portion 8. (This channel is created by first machining a rectangular groove 13 of 0.55 mm depth and 0.05 mm width along one side of the emitting point 4 from the shoulder 10 to a distance some 4.5 mm above. The groove 13 is then partially blocked using a fillet 14 of tungsten of 0.5 mm×3 mm×0.05 mm leaving a 0.05 mm×0.05 mm×3 mm interior channel 12 in the emitting point 4 which extends some 3 mm into the narrowest portion of the base structure 3.

FIG. 3 shows an alternative form of a liquid metal spray source consisting of a cylindrical base portion 21 some 5 to 7 mm in diameter which forms a reservoir 22 for a liquid metal 23 droplets of which are to be generated by the source. The bottom 24 of the base portion 21 has a conical emitting point 25 which projects some 2 mm below the bottom 24 of the base portion 21. As in the source previously described, the vertex angle of the emitting point 25 is 35 degrees. The radius of the tip of the emitting point 25 is somewhat greater than 25 μm. At the region where the emitting point 25 joins the remainder of the base portion 21 there is provided a hole 26 some 50 μm in the diameter. The hole 26 can be up to 0.5 mm in diameter. The hole 26 allows liquid metal to pass from the reservoir 22 to the emitting point 25 over the surface of which it flows by means of surface wetting at a rate which causes liquid metal drops to be discharged from the tip of the emitting point 25 under the influence of an electric field applied by means of a terminal 27 and an electrode 28. As before, arrangements can be made to heat the reservoir 22 to keep the metal in a liquid state, if it should prove necessary. If desired, more definite control over the rate of feed of the liquid metal 23 to the emitting point 25 can be achieved by means of a piston operating on the surface of the liquid metal 23 in the reservoir 22.

The materials used for both forms of liquid metal spray source have to be compatible with the liquid metal to be sprayed. The general criteria are that the source materials should be wetted by, but not soluble in, the metal to be sprayed. However, for some purposes some limited solubility of the source material in the liquid metal is permissible. For example, if the metal to be sprayed is gold, then the base structure 3 and the emitting point 4 of the first embodiment can be made of molybdenum and molybdenum or tungsten, respectively, though a carbon reservoir with tungsten emitter and feed arrangement as shown in FIG. 2(*a*) or 2(*b*) is preferred for reliable behaviour over prolonged periods. The above materials can be used for the reservoir 22 and emitting point 25 of the second embodiment.

For spraying aluminum or its alloys, a boron nitride/-titanium diboride composite can be used for the emitting points of both embodiments. For spraying gallium, either tungsten or tantalum can be used. For spraying silicon, a graphite emitting point is used.

We claim:

1. A source for producing a spray of drops of a liquid material under the action of an electric field, comprising a solid needle having an emitting point made of a material which is wetted by the liquid material and which has at most a low solubility in the liquid material, the emitting point having a vertex angle of between thirty and forty degrees, an annular structure surrounding the needle and from which the emitting point projects by a distance of between one and three millimeters, an extraction electrode, and supply and control means for supplying the liquid material to the emitting point at a controlled rate such that when an electric field is applied to the emitting point of a magnitude such as to disrupt the liquid material at the emitting point a spray of drops of the liquid material is produced, said supply and control means including a flow control device in the region where the needle emerges from the annular structure.

2. A source according to claim 1, wherein the flow control device comprises a spiral flow restrictor.

3. A source according to claim 2, wherein the spiral flow restrictor comprises a wire helix attached to the emitting point prior to its insertion in the annular structure.

4. A source according to claim 1, wherein the needle is a close fit in the orifice of the annular structure and the flow control device comprises a longitudinal slot cut in the needle.

5. A source according to claim 4, wherein the longitudinal slot is provided with a restrictor in the region where it emerges from the annular structure.

6. A source according to claim 1, wherein the annular structure is made of a material which is not wetted by the liquid material.

7. A source according to claim 1 wherein the emitting point has a tip radius of between 20μ and 100μ.

8. A source according to claim 7, wherein the tip radius of the emitting point is 60μ.

9. A source according to claim 1, wherein the vertex angle of the tip of the emitting point is 35°.

10. A source according to claim 1 for spraying gold wherein the annular structure and needle are made of molybdenum.

11. A source according to claim 1 for spraying gold wherein the needle is made of tungsten.

12. A source according to claim 1 for spraying aluminium or its alloys wherein the needle is made of a composite of boron nitride and titanium diboride.

13. A source according to claim 1 for spraying gallium wherein the needle is made from tungsten or tantalium.

14. A source according to claim 1 for spraying silicon wherein the needle is made of graphite.

15. A source for producing a spray of drops of a liquid material under the action of an electric field, comprising a solid needle having an emitting point made of a material which is wetted by the liquid material and which has at most a low solubility in the liquid material, the emittint point having a vertex angle of between thirty and forty degrees, an annular structure surrounding the needle and from which the emitting point projects by a distance of between one and three millimeters, an extraction electrode, and supply and control means for supplying the liquid material to the emitting point at a controlled rate such that when an electric field is applied to the emitting point of a magnitude such as to disrupt the liquid material at the emitting point a spray of drops of the liquid material is produced, wherein the needle has a shoulder formed in it so that the portion which projects beyond the base structure has a cross-section to form the emitting point which is smaller than that of the portion of the needle which is within the base structure.

16. A source according to claim 15, for the spraying of gold wherein the annular structure surrounding the needle at its point of projection is made of carbon and the emitting point is made of tungsten.

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